Optical Properties as Tracers of Water Mass Structure and Circulation Patterns in the Japan (East) Sea

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LONG-TERM GOALS

Our goals are to collect detailed optical and biogeochemical data sets in the global oceans to contribute to optical model parameterizations, algorithms for advanced ocean color satellite applications, and exploitation of satellite information to better understand biological-physical coupling in the oceans. In this project, we focus on the Japan/East Sea to improve our understanding of optical properties in the region, and apply this understanding to the study of circulation using optical remote sensing as a tracer of water masses.

OBJECTIVES

Our objectives are to coordinate research between US scientists at Scripps Institution of Oceanography, and scientists in Japan and Korea to characterize the detailed optical properties of different water masses in the Japan/East Sea (JES), and to specify the variability in the properties and their potential use as water mass tracers using *in situ* optics and remote sensing. Our overall hypothesis is that the JES can be defined in terms of 5 optical provinces with characteristic inherent and apparent optical properties (IOPs and AOPs) related to optically important seawater constituents. The 5 optical provinces include the Kuroshio Current intrusion through the Tsushima Strait, the East Korea Warm Current which entrains water from the Yellow Sea, coastal regions of Japan south of the Tsugaru Strait, the northern, sub-polar waters of the Tsushima Basin and Japan Basin, and finally, coastal regions north of the Tsugaru Strait.

APPROACH

Our approach is to carry out both detailed observational cruises, and collaborate with colleagues who measure a less detailed set of optics and biogeochemical properties. On the detailed cruises we measure the IOPs and AOPs within the JES, and fluorescence excitation/emission spectra using both an integrated *in situ* optical profiling system, and by analyzing water samples collected during hydrocasts so that the constituent component optical properties can be specified. Our *in situ* profiling system includes spectral downwelling irradiance and upwelling spectral irradiance and radiance (Ed,

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Eu, Lu), diffuse attenuation (K), absorption (a), scattering (c) and backscattering (bb). Combined with water sample analyses we will determine the most appropriate optical signatures to assist in the characterization of water mass structure and circulation, and we will develop specific parameterizations of IOPs as input to a radiative transfer model of ocean optics in the JES. The water analysis will also provide information about concentration and composition of optically important water constituents, which will be essential to understanding and interpretation of bulk optical properties. Combining data from *in situ* and laboratory measurements with radiative transfer modeling will allow us to achieve the best possible estimates of the IOPs and AOPs which are of most direct interest to water mass characterization. We will also test hypotheses concerning the episodic input of Asian dust, feedback of bio-optics on physical dynamics, and the use of satellite imagery of ocean color and sea surface temperature for the study of circulation in the JES.

In 1999 we initiated an ambitious field-sampling program on US, Korean, and Japanese ships. Coordination and data sharing with ONR-sponsored investigators and our Korean and Japanese colleagues are essential for success. We will implement detailed optical studies on Korean and Japanese cruises in selected provinces of the JES, and larger scale optical surveys on ONR-sponsored cruises, which will support various research activities in the area of physical oceanography and hydrography.

WORK COMPLETED

We have carried out a satellite study of a cold-core quasi-stationary eddy located off the coast of North Korea (Suh et al., 1999). In June 1999 we participated in the hydrographic survey cruise of the R/V Revelle in the Korean and Japanese waters of the JES. Following this cruise, we transferred some of our equipment onto the R/V Khromov and Dr. Sergei Zakharkov of the Pacific Oceanological Institute in Vladivostok carried out a mimimal set of observations in Russian waters for absorption, ocean reflectance using SIMBAD, and pigments. In October 1999 our colleauge, Young Sang Suh from the Korean National Fisheries Research Development Institute visited our lab for training, and we coordinated his training on the use of the new Biopsherical Instruments PRR 800 and Wetlabs Cstar (660 nm) transmissometer that NFRDI recently purchased. In 2000, these instruments will begin routine observations on NFRDI cruises in coastal waters of Korea. We have initiated planning for a regional ocean color algorithm workshop tentatively scheduled for September 2000 in Korea.

RESULTS

Spring and autumn satellite sea surface temperature observations have identified a recurring eddy at the terminal end of the East Korean Warm Current (e.g. Huh 1982). During late April 1997 this feature was evident in thermal infrared imagery from the NOAA AVHRR sensor and ocean color data from the Japanese OCTS sensor. The cold core had elevated chlorophyll concentrations, based on OCTS estimates, of greater than 3 mg/m^3 while the warmer surrounding waters had chlorophyll concentrations of 1 mg/m^3 or less. The elevated chlorophyll associated with this eddy has not been previously described. The eddy is also evident in SST images from autumn, but the SST in the core is warmer than in spring, and the warm jet flowing to the west of the eddy is also warmer in autumn compared to spring. The eddy forms at the northern extent of the East Korean Warm Current as those waters collide with the cold, south-flowing Liman Current over a topographic shelf about 1500 m deep. This region of the eddy formation appears to have a strong connection with the dynamics of the western part of the polar front eddy field that dominates surface mesoscale structure in the central East (Japan) Sea.

Analysis of the *in situ* data from the June-July cruise reveals strong vertical and horizontal gradients in the optical properties of the JES. Figure 1 illustrates the vertical profile for backscattering, absorption and attenuation coefficients obtained with our Hydroscat 6 and AC9 instruments in the central region of the JES. Figure 2 summarizes SeaWiFS match up data with our in water measurements of water leaving radiances. Figure 3 illustrates the JES spectral reflectance data compared to our large CalCOFI

data set. Application of SeaWiFS data (imagery not shown) revealed strong horizontal gradients in pigments related to the boundary of the sub-polar front and coastal upwelling near the Korean coast.

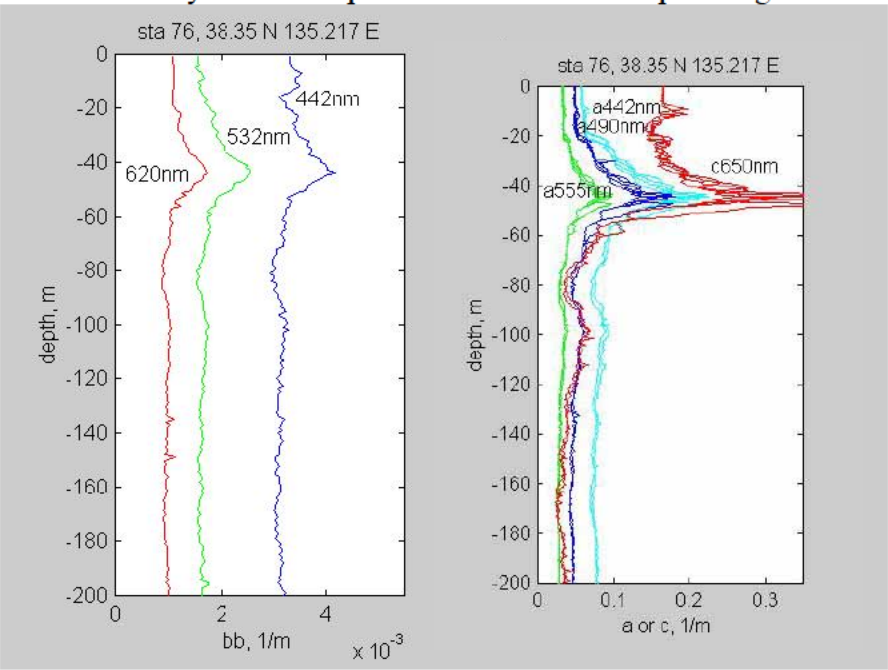

Figure 1. Profiles of spectral inherent optical properties in the central region of the JES. a. Backscatter coefficient obtained with HobiLabs Hydroscat 6. b. Absorption and attenuation coefficient obtained with Wet Labs AC-9.

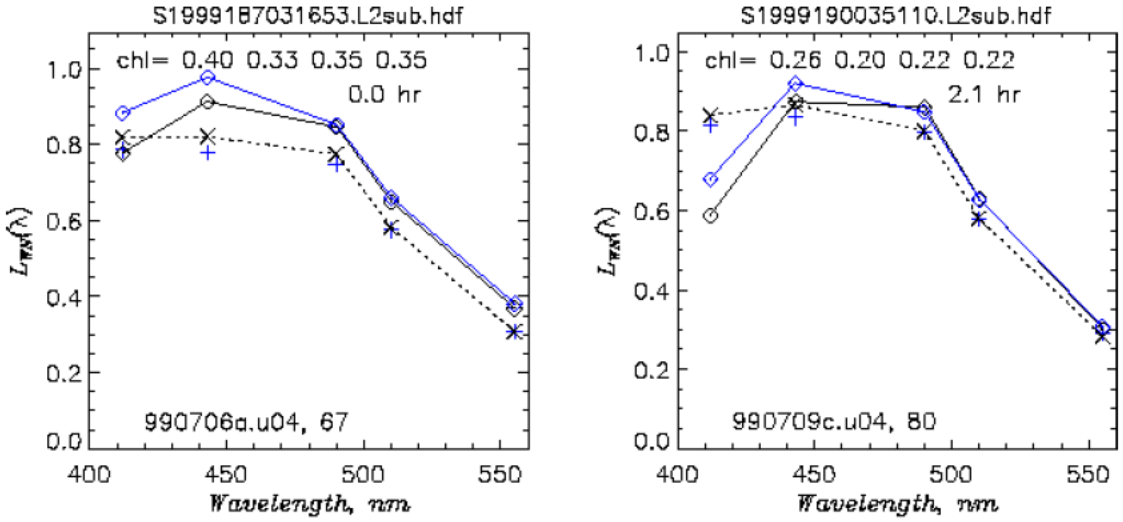

Figure 2. Comparison of SeaWiFS estimates of spectral water leaving radiance (L_{WN}) with our in situ estimates obtained with a Biospherical Instruments MER 2048.
□ = SeaWiFS estimate; +, X = replicate in situ estimates

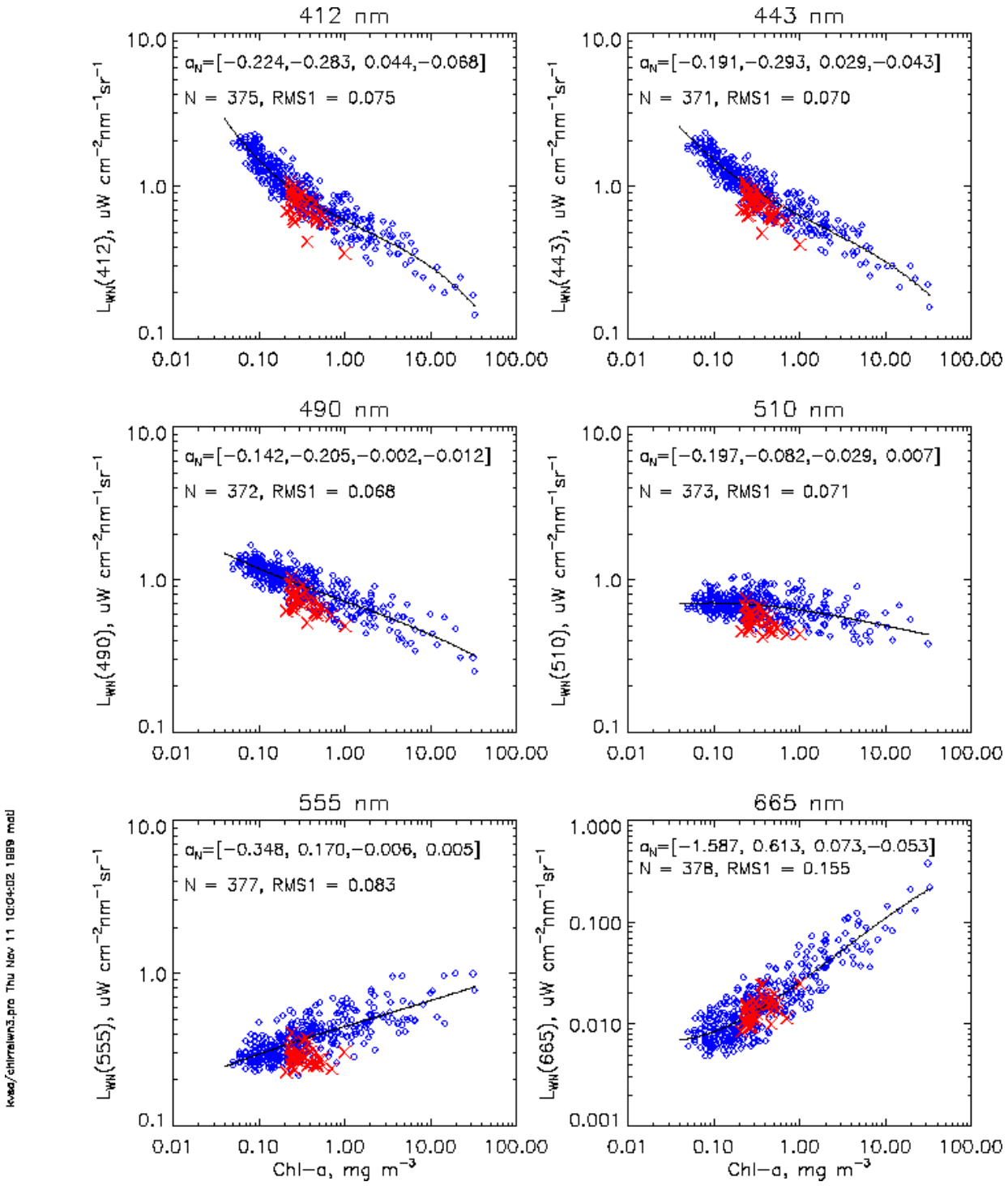

Figure 3. Scatter plots at SeaWiFS wavelengths of L_{WN} from in situ profiles versus chlorophyll a. Large X are JES data, small symbols are California Current data.

IMPACT/APPLICATIONS

We will integrate our comprehensive data to regional data sets collected by Japanese, Korean and Russian colleagues to develop a comprehensive understanding of the optical properties of the JES. Optical modeling and algorithm development will allow advanced applications of ocean color data to the retrieval of IOP and regional attenuation coefficients.

TRANSITIONS

We have published an article using drifters and satellites to describe a quasi-stationary eddy off the North Korean coast (Suh et al., 1999)

RELATED PROJECTS

This project is one of numerous projects funded under the ONR DRI Japan East Sea program. We plan to coordinate our optical and hydrographic analyses with other investigators.

REFERENCES

Suh, Y. S., S. B. Hahn, Y. Q. Kang, B. G. Mitchell, (1998), Study of a Recurring Anticyclonic Eddy off the Northeast Korean Coast using Satellite Ocean Color and Sea Surface Temperature Imagery. Journal of Advanced Marine Science and Technology Society (AMSTEC) (In Press)

PUBLICATIONS

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PATENTS

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